Time of Flight System for the MICE Experiment

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For the Padova-Milano Group
A. Guglielmi et al.

Legal Statement

- Most of this material has been plagiarized from
  - "TOF in Mice" by A. Guglielmi at 13 Jun 2002 detector meeting.
  - TOF section in detector chapter by Maurizio, Mauro, Alberto.

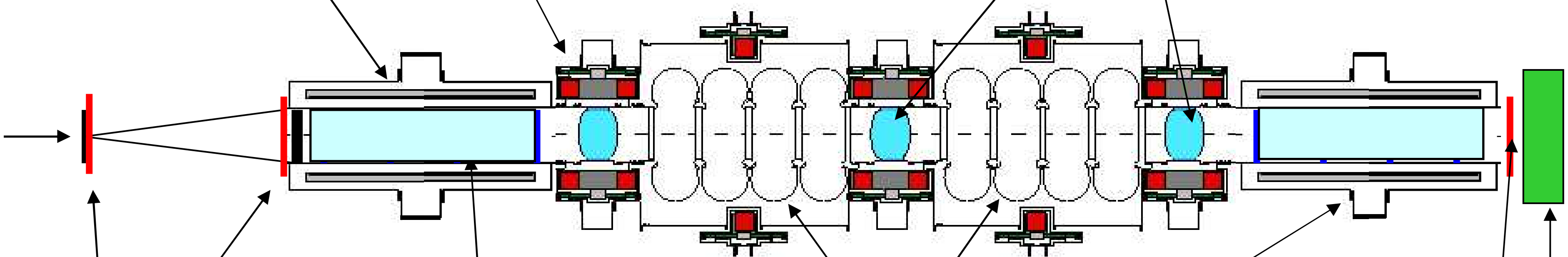
10% cooling of 200 MeV muons requires ~ 20 MV of RF

single particle measurements =>

measurement precision can be as good as $\Delta (\varepsilon_{out}/\varepsilon_{in}) =$

SC Solenoids;
Spectrometer, focus pair, compensation coil

Liquid H2 absorbers
or LiH ?



201 MHz RF cavities

T.O.F. I & II
Pion /muon ID
precise timing

Tracking devices:
He filled TPC-GEM (similar to TSLA R&D)
or sci-fi
Measurement of momentum angles and position

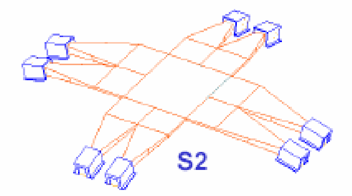
T.O.F. III
Precise timing

Electron ID
Eliminate muons that dec

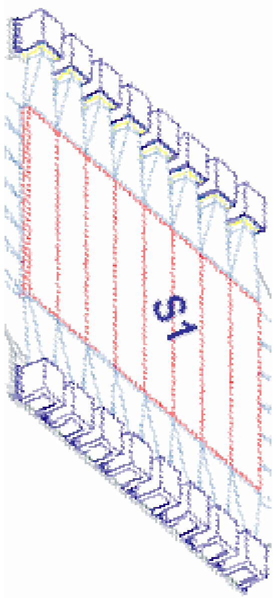
LOI submitted to PSI and RAL.
The two labs agreed to collaborate and RAL encourages submission of proposal. 2002: prepare prop

TOF I Station

- TOF I is located after 1st diffuser where beam comes into hall.
  - This at −15 meters from center of cooling cells.
  - TOF I is 12×12 cm^2 in size.
  - TOF I is composed of two planes oriented in X and Y respectively
    - Each plane is segmented into two slabs with phototubes on each end.
    - Each slab is $12 \times 6 \times 2.5$ cm^3.
    - Using Bicron BC-420 fast Scintillator.
  - Use Hamamatsu R4998 Phototubes on each end.
    - 0.7 ns rise time, 160 ps transit time jitter



TOF II AND TOF III Stations



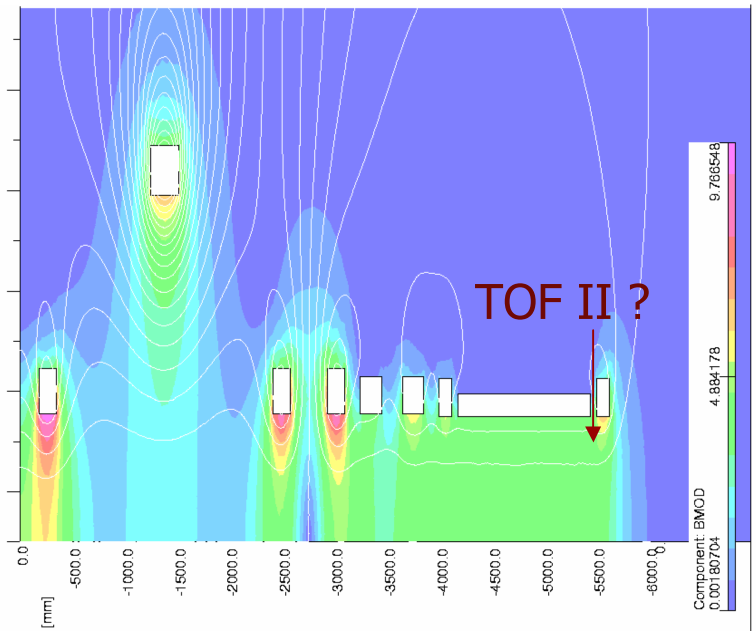
- TOF II (TOF III) is located before (after) the upstream (downstream) measurement solenoid.
  - This is at –5.544 meters from the center of the cooling cells.
  - TOF II, III are 40×40 cm^2 in size.
  - TOF II, III are composed of a single Y oriented plane.
    - The plane is segmented into 8 slabs.
    - Each slab is 40×6×2.5 cm^3.
      - There is ~1 cm overlap at the edges of the slabs to allow cross-calibration.
    - Bicron BC-404 Scintillator is used for these stations since it has a longer attenuation length than the BC-420 used in station I.
      - λ=1.7 meters.

TOF II and III continued

- The choice of phototube to use for the TOF II and TOF III stations is complicated by the presence of fringing magnetic field from the measurement solenoids.
  - The field situation is shown in the following transparencies.
  - The fast phototube used for TOF I (R4998) does not tolerate much magnetic field. The choices are
    - Shield the fast Hamamatsu R4998 phototubes.
    - Use the Hamamatsu R5505 fine mesh phototube which can handle fields up to ~1 Tesla.

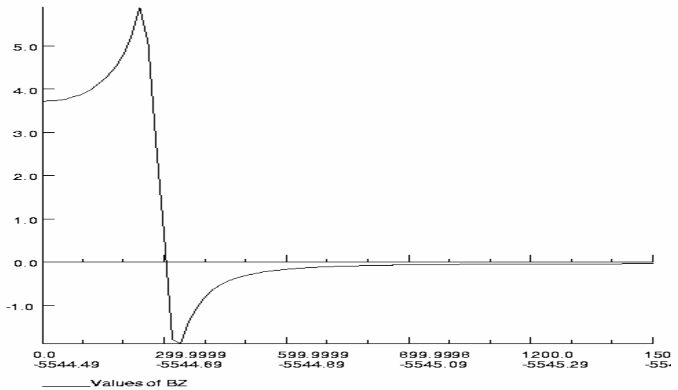
Magnetic Fields in the Vicinity of TOF II

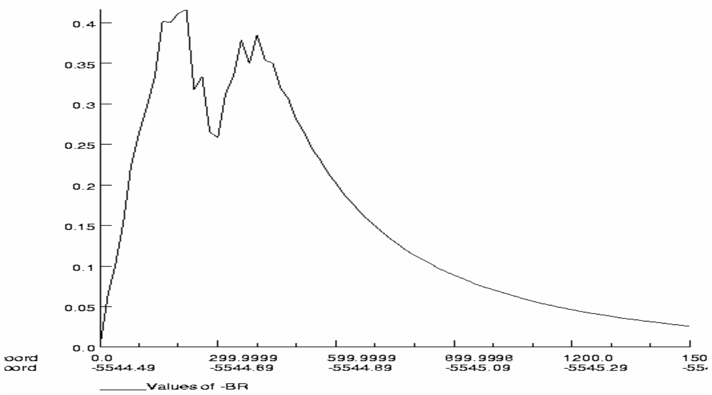
- Figure shows |B| from the cooling and measurement solenoids.
  - The parameters used in the calculation come from Rochford et al. (Mice note 10)
    - R_{coil} = 25 cm !!
    - The original sketches show R_{coil}=15 cm.
- The phototubes are placed in a place with high field.
  - This will be a design issue.



More on TOF II and TOF III Fields

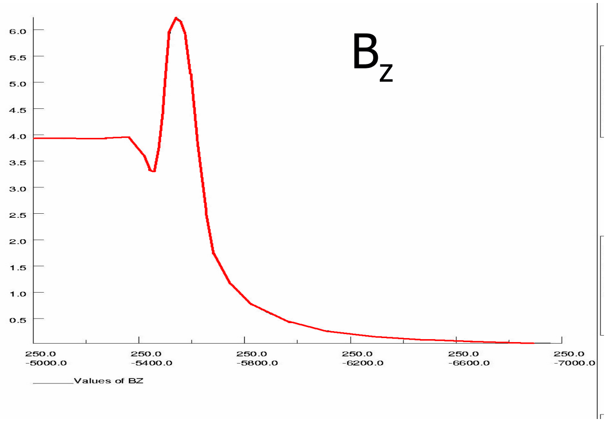
- Figures show $B_z(r)$ and $B_r(r)$ at the TOF II position.
- The phototubes appear to be position at $r \approx 23\text{-}25$ cm. (?)
  - $B_z \approx 5$ T
  - $B_r \approx 0.4$ T (this component along is along the phototube axis.
- Light guides could be used to put phototubes outside the coils (hopefully).
  - Just outside the coils:
    - $B_z = 2$ T
    - $B_r \approx 0.3$ T
  - These are my estimates, not Milano-Padova.

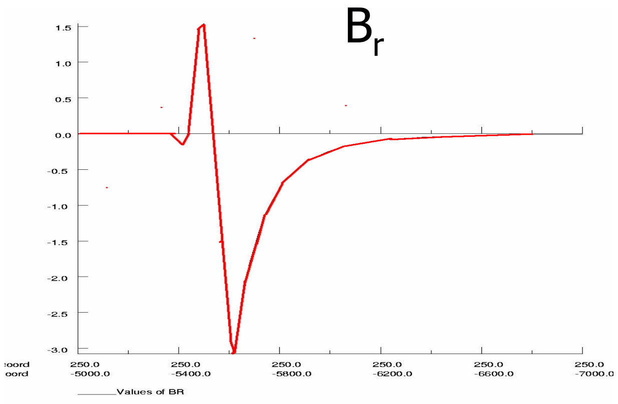




Even More on TOF Fields

- The figures on the right show B_z (upper) and B_r (lower) at r=25 cm as a function of z. This is appoximately the radial position that the phototubes would be placed.
  - Could we imagine positioning the TOFs ~2.5 meters from the end of the measurement solenoids where the fields will have dropped off?
    - This would add ~5 meters to the length. Can we still do that?





Phototube Properties

- The table shows a summary of the phototube properties
- The Hamamatsu R4998 is the faster tube and could be used for TOF I.
- The approach for TOF II, III could be either:
  - Multiple mu-metal shielding for a reduction by 10^6.
  - The use of the slower Hamamatsu R 5505 tube
    - How much would this compromise the triggering performance?

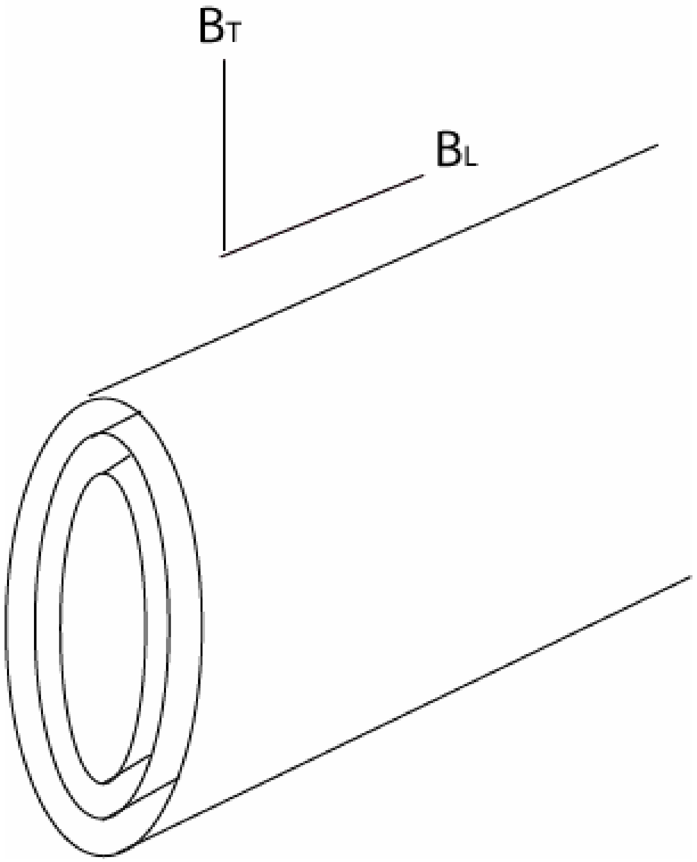
	R 4998	*R 5505*
Structure	Linear Focused	Fine Mesh
Stages	10	15
Gain	5.7×10^6	5×10^5 B=0 1.8×10^4 B=1 T
Rise Time	0.7 ns	1.5 ns
Transit Time	10 ns	5.6 ns
Transit Time Jitter	0.16 ns	0.35 ns

Shielding Phototubes

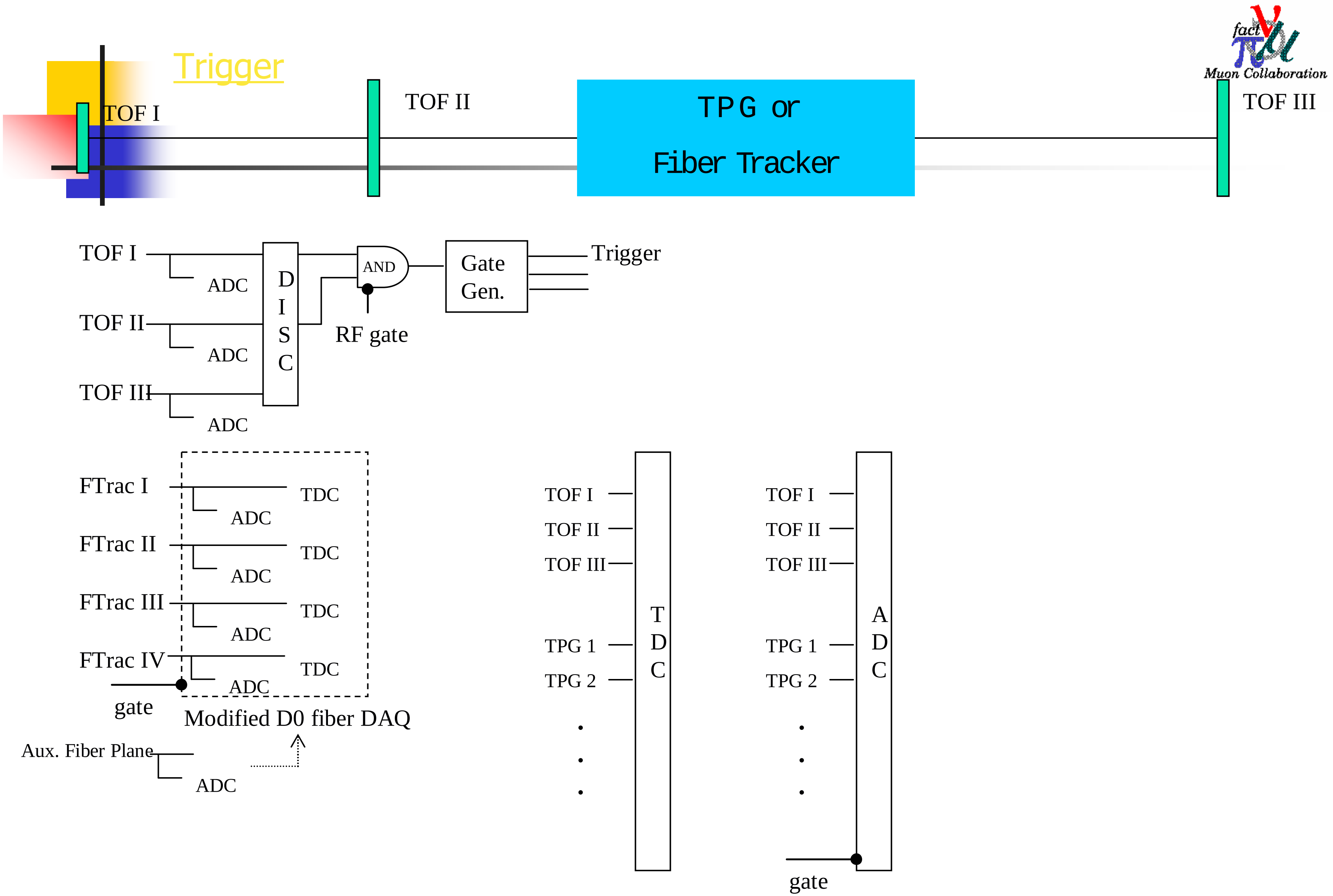
- Fields transverse to cylinder axis can be effectively reduced
  - Single cylinder: $S_i^T = \mu \frac{\delta}{2R_i}$
  - Three concentric cylinders:

$$S^T = \sum_{i=1}^{3} S_i^T + \sum_{i,j=1}^{3} S_i^T S_j^T \left(1-\frac{R_i}{R_j}\right)^2 + S_3^T \prod_{i=1}^{3} S_i^T \left(1-\frac{R_i}{R_{i+1}}\right)^2$$

- Numerical estimates using
  - Mu-metal μ=20000
  - Thickness δ=1 mm
  - Radii R_1=1.5, R_2=1.75, R_3=2 cm
    - Shielding factor of $S_T \approx 10^7$
    - Caution mu-metal may not survive very high fields.
- This does not effectively work for longitudinal fields.
  - B_L falls off as $e^{-l/D}$ which gives S_L~2-3.



Trigger



Muon Collaboration
TOF I
TOF II
TPG or
Fiber Tracker
TOF III
TOF I
ADC
TOF II
ADC
TOF III
ADC
D
I
S
C
AND
RF gate
Gate
Gen.
Trigger
FTrac I
TDC
ADC
FTrac II
TDC
ADC
FTrac III
TDC
ADC
FTrac IV
TDC
ADC
gate
Modified D0 fiber DAQ
Aux. Fiber Plane
ADC
TOF I
TOF II
TOF III
TPG 1
TPG 2
T
D
C
TOF I
TOF II
TOF III
TPG 1
TPG 2
A
D
C
gate

TOF Signal Processing

- From the HARP experience the signal processing issues are likely to be
  - Electronic Cross Talk in the discriminators and TDCs.
  - Time Stability of temperature, etc.
- HARP experiences implies that 150 ps intrinsic resolution can be achieved. This will require
  - High quality signal cables
  - High quality active splitters for PMT signal to TDC, ADC
  - Leading edge discriminators modified for cross talk
  - High quality delay cables
  - High quality signal regenerators to TDC inputs
  - State of the art TDCs
- Much of this will be available from HARP

Time of Flight System Costs

System	Item	New Costs (K€)	From Harp (K€)
Detector	40 PMT+μ metal	100	
	Scintillator	8	
	Light Guides	7	
	Mechanics		
Calibration System	Laser		80
	Optical System	15	
	Cosmic Ray Setup	5	
Electronics	QDC	10	
	TDC		10
	Scalers, MT, NIM		10
	Delay Boxes		5
	Active Splitters		5
	Crates, HV system	10	
	Discriminators	20	
	HV and Signal Cables		10
Total		180	120

What Needs to be Studied

- Understand what the field environment will be at the position of the PMTs.
- Photomultiplier Tube performance in our magnetic field environment.
- PMT coupling to directly to scintillator for TOF I
- Light guide shape and length for TOF II, III to live with field.
- Can we used the faster PMTs with shielding.
- Triggering for the MICE experiment.